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Art. V.—*An Investigation into the Influence of Sulphate of Ammonia on Stubble-sown Oat Crops in Victoria.*

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Introduction.

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A series of experiments at the Waite Institute, South Australia(5, 6), has shown that cereal crops when grown on land which has carried a crop the previous year respond to the application of nitrogenous fertilizers. It was with the object of determining whether a similar response occurs in the region of higher rainfall (20 inches or more per annum) in Victoria that this investigation was initiated. Oaten hay, being the cereal crop most sown on stubble in Victoria, was chosen for the experiment. Although Howell(3), thirty years ago, described experiments in which the application of 1 cwt. of sulphate of ammonia per acre increased the yields of hay crops by as much as 0.5 to 0.8 ton per acre, comparatively little attention has since been given to this matter.

Two series of field trials were conducted, one at Bannockburn, one at Buangor.

The Bannockburn plots were on the property of Mr. F. G. Mason, 4 miles from Bannockburn, which is 13 miles from Geelong on the railway line to Ballarat.

The plots were sown on a level area of uniform soil which has been derived from later Tertiary sediments and has undergone considerable leaching. The surface soil is a fine-textured sandy loam, light brown in colour and slightly acid. Below 8-9 inches there is a yellow clay subsoil which becomes lighter in colour with increase in depth.

The Buangor plots were on the property of Pickford Bros., about 1 mile from Buangor, which is 14 miles west of Beaufort. The plots were sown on a level piece of ground, but the soil is very variable, four different types of surface soil being present. These occur in patches of 1 square yard or less, and differ from each other in colour and in the amount of gravel they contain. This gravel, locally known as buckshot, consists mainly of iron oxide. All the types are slightly acid loams or clay loams, grey or brown in colour. The types of subsoil contain more clay and silt than the types of surface soil immediately above them. The buckshot gravel is irregularly distributed in depth. This variability of soil is typical of a large area in this part of the Western District of Victoria. This soil is derived from Ordovician marine sediments. Red box (*Eucalyptus polyanthemos*) and red stringybark (*Eucalyptus macrorrhyncha*) are the chief native trees.

The mechanical analyses of the various types of soil are shown in Table I.

At Bannockburn the total rainfall during the year was 19½ inches, of which 12 inches fell during the growing period of the crop (May–November). At Buangor the total rainfall was 23 inches, of which 14½ inches fell during the growing period of the crop. The monthly rainfall at both places and the number of days on which one or more points were recorded are shown in Table II.

TABLE I.—MECHANICAL ANALYSES OF THE SOILS AT BANNOCKBURN AND BUANGOR.

Site	Bannockburn.			Buangor.							
Soil type	..	..		Grey loam.		Grey rubbly loam.		Light brown clay loam.		Dark-brown clay loam.	
Depth, inches ..	0–8	8–11	28–32	0–5	18–24	0–8	21–24	0–11	11–20	0–8	8–12
Coarse sand ..	% 24·9	% 18·7	% 16·8	% 19·8	% 7·3	% 21·5	% 13·7	% 4·9	% 11·6	% 6·5	% 1·2
Fine sand	31·5	26·2	20·6	34·1	22·5	36·1	20·6	21·4	17·7	31·4	12·6
Silt	23·4	8·0	9·5	24·7	44·0	23·3	36·6	22·6	12·6	16·8	25·3
Clay	13·1	34·7	41·6	14·8	14·6	14·3	19·7	40·4	48·6	41·5	47·2
Loss on peroxide + acid treatment	5·0	7·0	7·7	5·6	1·8	3·5	2·3	4·7	0·1	2·0	3·1
Moisture	2·6	6·5	4·6	2·6	11·2	2·4	7·2	7·7	9·8	4·0	9·3
Gravel (in air-dry sample) per cent.	2·8	5·5	2·0	5·7	10·3	31·5	20·6	4·9	26·3	4·2	0·2
Total nitrogen, per cent.	0·07	..	..	0·11	..	0·13	..	0·11	..	0·09	..
Soil reaction pH ..	5·5	5·3	7·2	5·1	6·8	5·4	6·8	6·0	5·6	5·7	5·2

TABLE II.—THE MONTHLY RAINFALL AND THE NUMBER OF RAINY DAYS IN 1933 AT BANNOCKBURN AND AT BUANGOR.

—	Bannockburn.		Buangor.	
	Rainfall (Points).	Number of Rainy Days.	Rainfall (Points).	Number of Rainy Days.
January	34	3	57	5
February	30	3	..	..
March	53	3	137	4
April	129	5	105	5
May	262	9	224	10
June	124	8	114	8
July	170	8	205	10
August	171	12	240	16
September	128	4	281	12
October	70	4	129	6
November	288	3	267	4
December	491	7	540	10
Total	1,950	69	2,299	90

Experimental Procedure.

(*a*) *General.*—At each site the unit plot was 1/20th acre in area. Each plot received a basal dressing of 1½ cwt. of superphosphate per acre, and the oats were sown at the rate of 2 bushels per acre. The treatments included were:—

1. No nitrogen.
2. Sulphate of Ammonia, ¾ cwt. per acre.
3. Sulphate of Ammonia, 1½ cwt. per acre.

Commercial fertilizer mixtures were used to supply these dressings, and were drilled in with the seed. Each treatment was replicated four times, and the plots were arranged in the form of a "randomized block" (1) At harvest the hay obtained from each plot was weighed separately, and the yields of each treatment expressed as cwt. per acre. The grain yields were estimated from selected samples of the crop. (See section *c*). In addition, the features *b, c,* and *d* were studied by the methods described.

(*b*) *Changes in the Nitrate and the Ammonia Content of the Soil.*—The soil from each plot was sampled to a depth of 9 inches, at monthly intervals, throughout the growing period of the crop. A ¾-inch soil tube was used and nine cores were removed at distances of 9 yards apart along the midline of each plot. These were mixed to form the sample. A larger tube, 1¼ inches in diameter, was sometimes used, but the sampling method was otherwise the same. Moisture, ammonia, and nitrate were determined on each sample. The moisture contents were determined by drying the material in an oven at 105 deg. C. for 24 hours. The loss of weight is expressed as a percentage of the weight of the oven-dry soil. Nitrate was determined by Harper's phenoldisulphonic acid method(2), and ammonia by the method described in Appendix 1. It may be noted here that the amounts of nitrogen added to the top 9 inches of soil in the dressings of ¾ and 1½ cwt. sulphate of ammonia were 6½ and 13 parts per million of soil respectively.

(*c*) *Census Study of Growth and Yield of the Crop.*—A census study was included, so that the effect of the different quantities of sulphate of ammonia on the growth of the individual plants could be observed. The plants on fifteen one-foot lengths of drill-row on each plot were counted, and their development studied at intervals throughout the growing period.

Three weeks after germination the plants on each selected length of drill row were counted, and the average number of plants per foot was calculated, in the case of each plot, and each treatment. In October, the average number of plants per foot was again determined, together with the average number of tillers per plant. At harvest time the number of plants per foot, the number of ears per plant, and the number of spikelets and grains per ear were determined, together with the average weight of 1,000 grains and the bushel weight of the grain.

The grain from these samples and from fifteen other one-foot length of drill row on each plot was thrashed out and weighed, and the weights were used to estimate the yields of grain from each plot.

(*d*) *Nitrogen Content of the Crop.*—The nitrogen content of the crop on each plot was determined on the material collected in October for the tillering count. The plants on fifteen one-foot lengths of drill row on each plot were hand-pulled and the roots were later removed. The above-ground material was analyzed by the Kjeldahl method. The nitrogen content of the grain and of the straw at harvest were determined on the material from fifteen one-foot lengths of drill row from each plot. The amount of nitrogen removed from the soil was then calculated.

Details of Results.

Bannockburn.

(*a*) *General.*—The plots were sown on 5th May, 1933, the unit plot being a 14-row drill strip 88 yards long and 1/20th acre in area. (The heaviest dressing contained only 152 lb. each of superphosphate and sulphate of ammonia, instead of the desired 168 lb. of each.)

The plots were harvested on 24th November. The final hay yields and the estimated grain yields are given in Table III. The grain yields were estimated from the material of 30 1-foot lengths of drill row on each plot.

Table III.—Final Yields at Bannockburn.

Treatment.	Hay Yields (Cwt. per Acre).	Increment Due to Nitrogen (Cwt. per Acre).	Estimated Grain Yield (Bushels per Acre).	Increment Due to Nitrogen (Bushels per Acre).
No nitrogen	17·9	..	21·4	..
Sulphate of ammonia, $\frac{3}{4}$ cwt. per acre	31·8	13·9	36·8	15·4
Sulphate of ammonia, $1\frac{1}{2}$ cwt. per acre	38·3	20·4	41·8	20·4

The differences in the hay yields are significant*, the standard error of the mean being 0.84 cwt. per acre. The grain yield on the $\frac{3}{4}$ cwt. per acre treatment is significantly higher than that on the no-nitrogen treatment, the standard error of the mean being 2.14 bushels per acre.

* A "significant" difference is one that might be obtained by chance not more than once in twenty times. The term is used throughout this Paper with this meaning.

(*b*) *Nitrate and Ammonia Content of the Soil.*—Samples of the soil were analyzed at monthly intervals until 9th October. The results of the analysis are shown in Table IV., and are illustrated in the form of a graph in Figure 1.

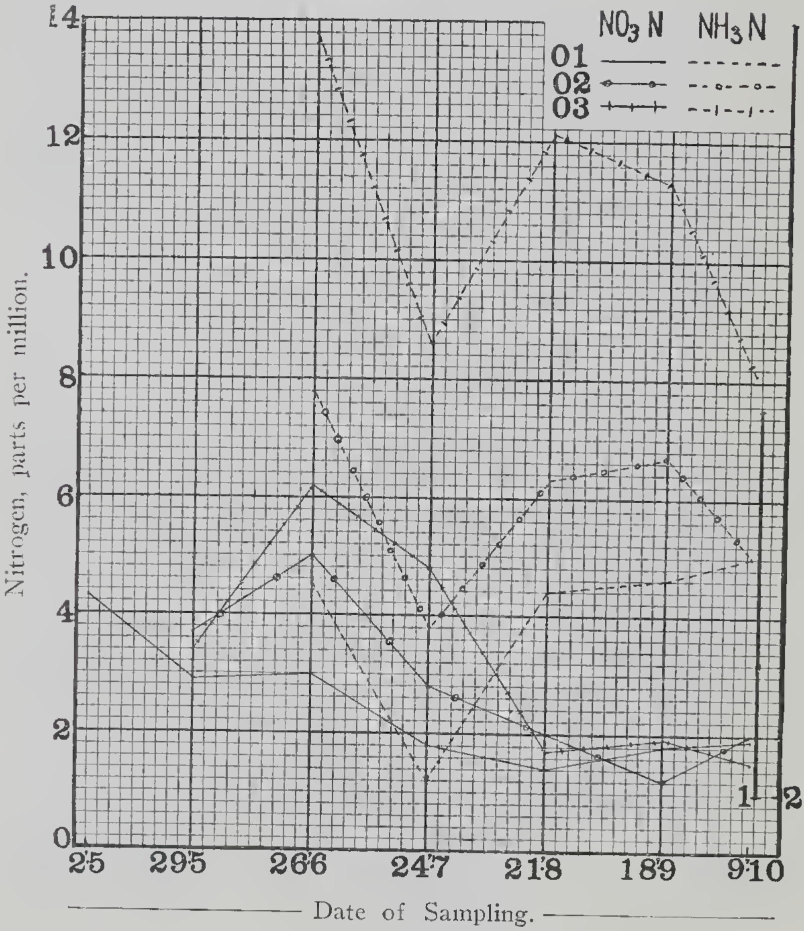

FIGURE 1.

Graph showing changes in nitrate and ammonia nitrogen content of the soil at Bannockburn during the growing period of the crop 1933.

1. Amount of nitrogen applied in ¾ cwt. sulphate of ammonia per acre.

2. Amount of nitrogen applied in 1½ cwt. sulphate of ammonia per acre.

Treatments.

01. No nitrogen.

02. Sulphate of ammonia—¾ cwt. per acre.

03. Sulphate of ammonia—1½ cwt. per acre.

TABLE IV.—CHANGES IN THE MOISTURE, NITRATE, AND AMMONIA CONTENT OF THE SOIL AT BANNOCKBURN.

Date.	Treatment.	Moisture Content Per Cent.	Nitrate Nitrogen Content—Parts per Million.	Ammonia Nitrogen Content—Parts per Million.
2.5.33	Before seeding	10·2	4·3	..
29.5.33	No nitrogen	13·2	2·9	..
	Sulphate of ammonia, ¾ cwt. per acre	11·3	*3·7*	..
	Sulphate of ammonia, 1½ cwt. per acre	10·0	3·4	..
26.6.33	No nitrogen	15·2	3·0	4·5
	Sulphate of ammonia, ¾ cwt. per acre	15·7	*5·0*	*7·8*
	Sulphate of ammonia, 1½ cwt. per acre	15·5	*6·2*	*13·8**
24.7.33	No nitrogen	12·6	1·8	1·2
	Sulphate of ammonia, ¾ cwt. per acre	13·2	2·8	*3·8*
	Sulphate of ammonia, 1½ cwt. per acre	13·5	*4·8*	*8·6**
21.8.33	No nitrogen	13·4	1·4	4·4
	Sulphate of ammonia, ¾ cwt. per acre	14·1	2·0	6·3
	Sulphate of ammonia, 1½ cwt. per acre	14·4	1·7	*12·1**
18.9.33	No nitrogen	11·7	1·8	4·6
	Sulphate of ammonia, ¾ cwt. per acre	10·8	1·2	6·7
	Sulphate of ammonia, 1½ cwt. per acre	9·6	1·9	*11·3**
9.10.33	No nitrogen	10·5	1·9	5·0
	Sulphate of ammonia, ¾ cwt. per acre	8·7	2·0	5·0
	Sulphate of ammonia, 1½ cwt. per acre	*7·0*	1·5	8·1

All figures in *italics* are significantly different from the corresponding figures for the no-nitrogen plots.

* These figures are also significantly different from those in the preceding row.

The chief points of interest are—

(1) The disappearance of the ammonia, whether by absorption by the plants, by leaching, or by change to nitrate or to other nitrogen compounds in the soil, was slow. Five months after the fertilizer was applied there was still appreciably more ammonia nitrogen in the soil of the 1½ cwt. per acre plots than in that of the no-nitrogen plots. This can be explained by assuming either that the addition of ammonium sulphate had a stimulating effect on the organisms which form ammonia in the soil, or that the nitrification (i.e., change to nitrate) was unusually slow in this soil. However, all the added ammonia on the ¾ cwt. per acre plots had disappeared during the first five months after application.

(2) In June and July there was a significantly higher content of nitrate nitrogen in the soil of the sulphate of ammonia plots. The nitrate content was then appreciably higher on the $1\frac{1}{2}$ cwt. per acre plots than on the $\frac{3}{4}$ cwt. per acre plots. This was in accordance with general experience, as was the low value for the nitrate content of the soil in September and October.

It must be noted that the soil was sampled between the drill rows, so that the samples did not exactly represent the soil on which the plants were growing.

(*c*) *Census Study of Growth and Yield of Crop.*—The results of the census study are summarized in Table V.

TABLE V.—RESULTS OF THE CENSUS STUDY AT BANNOCKBURN.

——	No Nitrogen.	Sulphate of Ammonia, ¾ Cwt. per Acre.	Sulphate of Ammonia, 1½ Cwt. per Acre.
(1) *Population.*			
Mean number grains sown per foot, 5th May, 1933	16·2	16·2	16·2
Germination—Mean number plants per foot, 19th June, 1933	12·7	11·3	*10·3*
Mean number plants per foot, 9th October, 1933	13·2	12·3	*10·9*
Mean number plants per foot at harvest, 24th November, 1933	11·7	11·1	8·6
Percentage survival of plants to harvest ..	89·0	90·0	79·0
(2) *Tillering.*			
Average number of tillers per plant, 9th October, 1933	3·5	*5·2*	*6·2**
†Estimated green weight of the crop (cwt. per acre), 9th October, 1933	37·4	*67·6*	*82·7**
Average number of tillers per foot, 9th October, 1933	45·3	63·4	*67·6*
(3) *Ears and Grains.*			
Average number of ears per plant ..	1·2	1·6	*2·0*
Average number of ears per foot	14·2	17·3	17·1
Percentage of tillers formed which produce ears	31·4	27·4	25·3
Average number of spikelets per ear ..	7·1	*9·8*	*10·6**
Average number of grains per spikelet ..	1·82	1·89	*1·90*
Average number of grains per ear ..	12·8	*18·6*	*20·0**
Average number of sterile grains per ear ..	0·46	0·67	0·58
Average weight of 1,000 grains (grams) ..	28·3	29·5	29·2
Bushel weight of the grain, lb. per bushel ..	36·7	37·7	38·2
Estimated grain yield, bushels per acre ..	21·4	36·8	41·8

All figures in *italics* are significantly different from the corresponding figures for the no-nitrogen plots.

* These figures are also significantly different from those in the preceding column.

† This figure indicates the amount of silage that could have been obtained from the crop. The estimated air-dry weights at this stage are given in Table VII.

The chief points of interest are as follows:—

(1) There was a depression of germination on the sulphate of ammonia plots, the effect being more marked on the 1½ cwt. per acre plots. Germination was later on the sulphate of ammonia plots than on the no-nitrogen plots.

(2) There was an increased formation of tillers on the sulphate of ammonia plots, and this more than compensated for the depression of germination. However, there was a lower percentage survival of tillers to harvest on the sulphate of ammonia plots. This was a direct result of the large number of tillers formed, and the competition between them.

(3) There was an increase, both in the number of ears produced per plant and in the size of the ears, on the sulphate of ammonia plots. Nevertheless, there were no more ears produced per foot of drill row on the 1½ cwt. per acre plots than on the ¾ cwt. per acre plots.

(4) The main reason for the higher yield of grain on the sulphate of ammonia plots than on the no-nitrogen plots was the larger number of grains per ear. There were also more ears per plant and per foot of drill row (see 3).

(5) There was no appreciable difference in the average size of the individual grains from the various treatments, but the bushel weight was slightly greater in the case of the grain from the sulphate of ammonia plots.

(6) The crop on the no-nitrogen plots showed marked yellowing in July and August, but the sulphate of ammonia plots were a healthy bright green in colour. Although the no-nitrogen plots showed superior growth in May and June, the sulphate of ammonia plots showed superior growth in the next four months. The plots that had received ¾ cwt. and 1½ cwt. per acre were respectively 3 inches and 6 inches taller than the no-nitrogen plots in October. The crop was also much denser on the sulphate of ammonia plots than on the no-nitrogen plots. At harvest, however, there was little difference in height between the crops on the various plots.

(*d*) *Nitrogen Content of the Crop.*—The nitrogen content of the crop in October, and that of the grain and straw at harvest, are shown in Table VI.

Table VI.—Nitrogen Content as Percentage of air-dry Material, in October and at Harvest.

Treatment.	Percentage of Nitrogen in Crop on 9th October, 1933.	Percentage of Nitrogen at Harvest.	
		In Grain.	In Straw.
No nitrogen	1·07	1·46	0·37
Sulphate of ammonia, ¾ cwt. per acre	1·06	1·46	0·37
Sulphate of ammonia, 1½ cwt. per acre	1·07	1·47	0·39

The added nitrogen had no effect on the percentage of nitrogen in the crop. Richardson and Fricke(6) have also shown that dressings of sulphate of ammonia applied at the rates of less than

1 cwt. per acre did not appreciably increase the nitrogen percentage of the grain or of the straw of barley. Larger dressings caused a marked increase in the nitrogen percentage of both the grain and the straw.

The total amounts of nitrogen removed by the crop per acre under each treatment was then calculated. The results, as well as the quantity of nitrogen applied to the soil per acre under each treatment, are shown in Table VII.

TABLE VII.—TOTAL NITROGEN REMOVED BY THE VARIOUS CROPS.

Treatment.	Nitrogen Applied in Fertilizer (lb. p.a.).	October Material.		Harvest Material.				Total Nitrogen Removed by crop (lb. p.a.).
				Grain.		Straw.		
		Dry Weight (lb. p.a.).	Nitrogen Removed (lb. p.a.).	Weight (lb. p.a.).	Nitrogen Removed (lb. p.a.).	Weight (lb. p.a.).	Nitrogen Removed (lb. p.a.).	
No nitrogen ..	..	2,036	21·8	856	12·50	1,144	4·23	16·7
Sulphate of ammonia, ¾ cwt. per acre ..	17·8	3,831	36·1	1,472	21·49	2,088	7·73	29·2
Sulphate of ammonia, 1½ cwt. per acre ..	35·6	4,452	41·6	1,672	24·58	2,608	10·17	34·7

It will be noticed that the total nitrogen content in the above-ground portions of the crop was greater in October than at harvest. Knowles and Watkins(4) have shown that there is a migration of the various plant nutrients from the above-ground portions of the wheat plant during the later stages of the life history.

BUANGOR.

(*a*) *General*.—The plots were sown on 9th May, 1933. The unit plot was a 15-row drill strip 83 yards long, the area being 1/20th acre. The outside row on each side was removed immediately before the plots were harvested. The area at harvest was 1/25th acre.

The final hay yields and the estimated grain yields are shown in Table VIII. The grain yields were estimated from thirty 1-foot lengths of drill row from each plot.

TABLE VIII.—FINAL YIELDS AT BUANGOR.

Treatment.	Hay Yields (Cwt. per Acre).	Increment Due to Nitrogen (Cwt. per Acre).	Estimated Grain Yield (Bushels per Acre).	Increment Due to Nitrogen (Bushels per Acre).
No nitrogen	27·8	..	35·9	..
Sulphate of ammonia, ¾ cwt per acre	43·9	16·1	46·2	10·3
Sulphate of ammonia, 1½ cwt per acre	57·4	29·6	59·5	23·6

All the above differences are significant, the standard error of the mean being 1.6 cwt. per acre in the case of the hay yields, and 2.7 bushels per acre in the case of the grain yields.

(*b*) *Nitrate and Ammonia Content of the Soil.*—Samples of the soil were analyzed at monthly intervals until 3rd October. The results are shown in Table IX., and are illustrated in the form of a graph in Fig. 2.

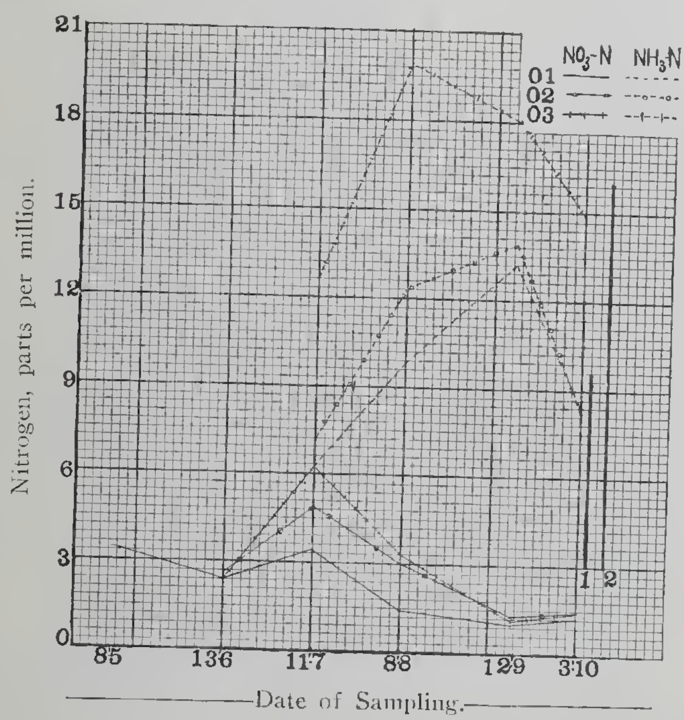

FIGURE 2.

Graph showing changes in nitrate and ammonia nitrogen content of the soil at Buangor during the growing period of the crop 1933.

1. Amount of nitrogen applied in ¾ cwt. sulphate of ammonia per acre.

2. Amount of nitrogen applied in 1½ cwt. sulphate of ammonia per acre.

Treatments.

01. No nitrogen.

02. Sulphate of ammonia—¾ cwt. per acre.

03. Sulphate of ammonia—1½ cwt. per acre.

TABLE IX.—CHANGES IN THE MOISTURE, NITRATE, AND AMMONIA CONTENT OF THE SOIL AT BUANGOR.

Date.	Treatment.	Moisture Content Per Cent.	Nitrate Nitrogen Content—Parts per Million.	Ammonia Nitrogen Content—Parts per Million.
9.5.33	Before seeding	10·7	3·4	..
13.6.33	No nitrogen	22·5	2·4	..
	Sulphate of ammonia, ¾ cwt. per acre	22·5	2·6	..
	Sulphate of ammonia, 1½ cwt. per acre	22·5	2·4	..
11.7.33	No nitrogen	21·3	3·4	6·2
	Sulphate of ammonia, ¾ cwt. per acre	21·8	*4·9*	7·2
	Sulphate of ammonia, 1½ cwt. per acre	22·6	*6·2**	*12·6**
8.8.33	No nitrogen	22·4	1·4	9·8
	Sulphate of ammonia, ¾ cwt. per acre	20·6	3·0	12·3
	Sulphate of ammonia, 1½ cwt. per acre	20·0	*3·3*	*19·9**
12·9·33	No nitrogen	22·0	1·0	13·2
	Sulphate of ammonia, ¾ cwt. per acre	22·0	1·3	13·9
	Sulphate of ammonia, 1½ cwt. per acre	22·0	1·1	*18·0*
3.10.33	No nitrogen	19·8	1·2	8·4
	Sulphate of ammonia, ¾ cwt. per acre	21·7	1·4	8·2
	Sulphate of ammonia, 1½ cwt. per acre	21·1	1·4	14·9

All figures in *italics* are significantly different from the corresponding figures for the no-nitrogen plot.
* This figure is also significantly different from that in the preceding row.

The chief points of interest are:—

(1) As was the case at Bannockburn, the plots that had received 1½ cwt. of sulphate of ammonia per acre still showed an appreciably higher ammonia content than the no-nitrogen plots five months after the application. It was expected that all would have been absorbed by the plants, changed to other nitrogen compounds, or been leached from the surface soil by this time. The excess ammonia in the plots that had received ¾ cwt. of sulphate of ammonia per acre had, however, all disappeared during the first five months.

(2) The sulphate of ammonia plots had, in July and August, more nitrate nitrogen than the no-nitrogen plots. The nitrate content of the soil was then highest on the 1½ cwt. per acre plots.

The results of these soil analyses are not as reliable as those of the Bannockburn soil. The errors of sampling are large because the soil is variable.

The samples were taken from between the drill rows, and so do not accurately represent the soil on which the plants were growing.

(*c*) *Census Study of Growth and Yield of Crop.*—The results of the census study of the crop are summarized in Table X.

TABLE X.—RESULTS OF THE CENSUS STUDY AT BUANGOR.

—	No Nitrogen.	Sulphate of Ammonia, ¾ Cwt. per Acre.	Sulphate of Ammonia, 1½ Cwt. per Acre.
(1) *Population.*			
Mean number grains sown per foot, 9th May, 1933	16·1	16·1	16·1
Germination—Mean number plants per foot, 30th June, 1933	11·2	11·7	11·6
Mean number plants per foot, 3rd October, 1933	11·6	12·5	11·6
Mean number plants per foot at harvest, 9th December, 1933	10·6	11·3	11·2
Percentage survival of plants to harvest ..	92·5	90·5	97·0
(2) *Tillering.*			
Mean number tillers per plant, 3rd October, 1933	3·8	*5·2*	*6·0**
†Estimated green weight of crop (cwt. per acre), 3rd October, 1933	44·3	*81·5*	*101·4*
Mean number tillers per foot, 3rd October, 1933	41·4	63·5	69·3
(3) *Ears and Grains.*			
Mean number ears per plant	1·3	1·7	*1·8*
Mean number ears per foot	14·0	18·9	*20·0*
Percentage of tillers formed which produce ears	34·8	29·8	27·8
Mean number spikelets per ear	9·9	10·4	11·2
Mean number grains per spikelet	1·91	1·90	1·88
Mean number grains per ear	18·9	19·4	21·2
Mean number sterile grains per ear ..	0·66	0·61	0·66
Mean weight of 1,000 grains (grams) ..	32·2	31·7	33·4
Bushel weight (lb. per bushel)	37·0	39·0	40·2
Estimated grain yield (bushels per acre) ..	35·9	46·2	59·5

All figures in italics are significantly different from the corresponding figures for the no-nitrogen plots.

* This figure is also significantly different from that in the preceding column.

† This figure indicates the amount of silage or green feed that could have been obtained. The estimated air-dry weights of the crop at this stage are shown in Table xii.

The chief points of interest are as follows:—

(1) There was no depression of germination on the sulphate of ammonia plots.

(2) There was an increased formation of tillers on the sulphate of ammonia plots.

(3) There was an increase in the number of ears produced per plant, as well as in the size of the ears on the sulphate of ammonia plots.

(4) The higher yield on the sulphate of ammonia plots than on the no-nitrogen plots was mainly due to an increase in the number of ears per foot of drill row. There was also an increase in the size of the ear.

(5) There was no appreciable difference in the size of the individual grains from the various treatments. The bushel weight was slightly higher in the case of the grain on the sulphate of ammonia plots.

(6) In July and August yellowing was widespread—particularly on the no-nitrogen plots. It was particularly noticeable on the light-brown patches of soil. In August and September the crop on the sulphate of ammonia plots was definitely taller than that on the no-nitrogen plots. This difference in height increased until at harvest the plants on the $1\frac{1}{2}$ cwt. plots were at least 9 inches taller than those on the no-nitrogen plots. Those on $\frac{3}{4}$ cwt. plots were intermediate in height.

(*d*) *Nitrogen Content of the Crop.*—The nitrogen content of the crop in October, and of the grain and straw at harvest, is shown in Table XI.

TABLE XI.—NITROGEN CONTENT AS PERCENTAGE OF AIR-DRY MATERIAL, IN OCTOBER AND AT HARVEST.

Treatment.	Percentage of Nitrogen in Crop on 9th October, 1933.	Percentage of Nitrogen at Harvest.	
		In Grain.	In Straw.
No nitrogen	1·05	1·44	0·35
Sulphate of ammonia, $\frac{3}{4}$ cwt. per acre	1·06	1·44	0·36
Sulphate of ammonia, $1\frac{1}{2}$ cwt. per acre	1·10	1·46	0·36

In October there was no appreciable difference in the nitrogen percentage of the crops grown with the various treatments. At harvest there was no appreciable difference in the nitrogen percentage of the grain or the straw.

The actual amounts of nitrogen removed by the crop, together with that applied in the fertilizer dressing, appear in Table XII.

TABLE XII.—TOTAL NITROGEN REMOVED BY THE VARIOUS CROPS.

Treatment.	Nitrogen Applied in Fertilizer (lb. p.a.).	October Material.		Harvest Material.				Total Nitrogen Removed (lb. p.a.).
				Grain.		Straw.		
		Dry Weight (lb. p.a.).	Nitrogen Removed (lb. p.a.).	Weight (lb. p.a.).	Nitrogen Removed (lb. p.a.).	Weight (lb. p.a.).	Nitrogen Removed (lb. p.a.).	
No nitrogen ..	..	1,965	20·6	1,436	20·68	1,796	6·29	27·0
Sulphate of ammonia, ¾ cwt. per acre ..	17·8	3,677	38·9	1,848	26·61	3,138	11·30	37·9
Sulphate of ammonia, 1½ cwt. per acre ..	35·6	4,034	44·4	2,380	34·75	4,161	14·98	49·7

It will be noticed that the total nitrogen in the crop was greater at harvest than when the October material was collected. This material was collected at an earlier stage of maturity than that at Bannockburn, and probably had not developed the maximum nitrogen content.

Comparison of Results from Bannockburn and Buangor.

The final yields at Bannockburn and at Buangor given in Tables III. and VIII. respectively may be compared as follows:—

A. FINAL YIELDS.

Hay Yields.—At each place the increment in yield obtained with the first ¾ cwt. of sulphate of ammonia per acre was greater than that obtained with the second ¾ cwt. per acre. The yield on the no-nitrogen plots was greater at Buangor than at Bannockburn, and the actual increments in yield due to sulphate of ammonia were greater at Buangor. At both places the yield was more than doubled by applying 1½ cwt. per acre.

Grain Yields.—At Buangor the first ¾ cwt. of sulphate of ammonia increased the yield by 10 bushels per acre (=25 per cent. of the no-nitrogen yield). The second ¾ cwt. increased the yield by an equal amount. At Bannockburn the first ¾ cwt. increased the yield by 15 bushels (=70 per cent. of the no-nitrogen yield), the second ¾ cwt. increased it only by 5 bushels. The grain yields were higher at Buangor than at Bannockburn.

If sulphate of ammonia is valued at 9s. 9d. per ¾ cwt. applied (market price = £12 7s. 6d. per ton f.o.r.) oaten hay at 30s. per ton, and oats at 1s. 6d. per bushel, the profit or loss of applying each successive ¾ cwt. per acre is shown in Table XIII.

TABLE XIII.—THE PROFIT (+) OR LOSS (—) PER ACRE OF APPLYING INCREASING DRESSINGS OF SULPHATE OF AMMONIA.

Due to—	Bannockburn.		Buangor.	
	For Hay.	For Grain.	For Hay.	For Grain.
	s. d.	s. d.	s. d.	s. d.
First ¾ cwt. per acre	+ 11 6	+ 13 0	+ 14 6	+ 5 0
Second ¾ cwt. per acre ..	+ 1 0	− 2 0	+ 11 6	+ 8 0
Total 1½ cwt per acre ..	+ 12 6	+ 11 0	+ 35 6	+ 13 0

With these assumed prices, 1½ cwt. per acre with a suitable dressing of superphosphate, is profitable at both places when oats are grown for hay.

If oaten hay were valued at 20s. per ton the profits of applying successive ¾ cwt. dressings at Bannockburn would have been + 4s. 6d. and — 3s., and at Buangor they would have been + 6s. 6d. and + 4s., so that ¾ cwt. per acre would be the more profitable quantity to apply at Bannockburn.

At Bannockburn, ¾ cwt. per acre is the more profitable amount to apply if the oats are grown for grain. At Buangor 1½ cwt. per acre is the more profitable amount.

B. NITRATE AND AMMONIA CONTENT OF THE SOIL.

At both places there was, from the time of application onwards, a steady decline in the amount of ammonia that the sulphate of ammonia plots contained in excess of the no-nitrogen plots. There was a definite seasonal change in the ammonia content of the soil, and the graph representing this was of the same form at each place, although the ammonia content of the soil was somewhat higher at Buangor than at Bannockburn. It is usual for the nitrate content of the soil carrying a cereal crop to be very low in September and October.

At both places there was a steady drop in the nitrate content of the soil in the no-nitrogen plots from seeding to October. The nitrate content of the soil was lower at Buangor than at Bannockburn. On the sulphate of ammonia plots there was an increase in the nitrate content of the soil from the end of June to the beginning of August. This was largest on the 1½ cwt. plots. The increases in nitrate content on the sulphate of ammonia plots was almost equal at each place.

C. Census Studies of Growth and Yield of Crop.

(1) *Population.*—At both places the number of grains sown per foot of drill row was slightly over 16.

The germination on the no-nitrogen plots was higher at Bannockburn than at Buangor. At Bannockburn, the sulphate of ammonia delayed germination, and caused a definite depression of germination. This was probably due to the osmotic power of the concentrated solution formed in the soil, which had an injurious action on the seeds. It did not occur at Buangor, where the soil is heavier.

In October, there were in many cases actually more plants per foot of drill row than in June. This was because grains which had failed to germinate in the dry soil did so after the heavy rains in June (108 points fell at Bannockburn between 22nd June and 28th June; at Buangor light rains towards the end of June were followed by 45 points on 10th July).

At both places there was a slightly lower percentage survival of plants till harvest on the no-nitrogen plots than on the sulphate of ammonia plots. At Bannockburn, however, the no-nitrogen plots still contained the most plants per foot of drill row.

(2) *Tillering.*—At each place most tillers were formed per plant and per foot of drill row on the sulphate of ammonia plots that had received 1½ cwt. per acre, and least were formed on the no-nitrogen plots.

(3) *Ears and Grains.*—At Buangor the applied nitrogen caused an increase in the number of ears produced per plant, and in the number of spikelets and grains per ear. The number of ears per foot of drill row was also increased. There was little difference in the size of the individual grains, but the bushel weight was slightly higher on the sulphate of ammonia plots.

Similar results were obtained at Bannockburn, except that there was no difference between the number of ears formed per foot of drill row on the ¾ cwt. per acre and on the 1½ cwt. per acre plots.

The higher yields at Buangor than at Bannockburn were due more to larger ears and larger grains than to an increase in the number of ears.

D. Nitrogen Content of the Crop.

October Material.—The results obtained at the two places are not comparable as the material from Bannockburn was at a later stage of maturity than that from Buangor. At neither place was there any appreciable difference in the nitrogen percentage of the crops due to the various treatments.

Harvest Material.—Neither the grain nor the straw showed any appreciable difference in nitrogen percentage due to the various treatments. At neither place was the nitrogen applied in the fertilizer completely recovered in the crop. However, about two-thirds was recovered in the crop; the amount of the heavier dressing recovered being higher at Buangor than at Bannockburn.

Summary.

The effect of ammonium sulphate on the growth and yield of stubble-sown oaten hay crops has been studied on field plots at Bannockburn and Buangor, where the rainfall for 1933 was 19.5 and 23 inches respectively. At each site the field plots were arranged in the form of a randomized block.

The final yields of hay and of grain were markedly increased by an application of sulphate of ammonia at seeding. At both sites a dressing of $\frac{3}{4}$ cwt. per acre gave an increase in the hay yield and in the grain yield, which would be economic at current prices. The increase given by a second $\frac{3}{4}$ cwt. per acre was likewise economic for hay at both places, and for grain at Buangor.

Although the ammonia content of the soil is not generally thought to have any relationship with the crop yield, it was found that marked variations occurred in the ammonia content of the soil throughout the growing period of the crop. The amount of ammonia that the sulphate of ammonia plots contained in excess of the no-nitrogen plots became gradually less in amount as the season advanced. The change was slow, requiring more than five months for completion on the $1\frac{1}{2}$ cwt. per acre plots. The nitrate content of the soil increased from June to August on the sulphate of ammonia plots.

Census studies showed an increase in the tillering of the plants, an increase in the number of ears produced and in the size of the ears, on the sulphate of ammonia plots. There was also a slight increase in the bushel weight of the grain. At Bannockburn, but not at Buangor, there was a depression of germination on the sulphate of ammonia plots.

The nitrogen percentage of the crops in October showed no differences between the different treatments, nor was there any difference in the nitrogen content of the grain or straw at harvest.

The total nitrogen removed by the crop on the sulphate of ammonia plots was in all cases more than that removed by the crop on the corresponding no-nitrogen plots, but the difference in nitrogen removed by the crop was less than two-thirds the difference in the amounts of nitrogen applied in the corresponding fertilizer dressings.

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Appendix.

Method Used to Determine the Ammonia Content of the Soil.

Twenty-five grams of soil are leached with 250 c.c. of N/10 hydrochloric acid. The soil is shaken with 100 c.c. of the acid, and is washed on to a filter paper in a Buchner funnel. The acid is slowly drawn through the soil on the filter paper. When just sufficient acid to wet the soil remains in the funnel, a further 25 c.c. are added. This is repeated until the whole 250 c.c. of acid have been drawn through the soil.

The washings are distilled with magnesium oxide into a measured amount of N/50 HCl, and the titration is completed with N/50 NaOH.